APPENDIX G:

Review Comments

by

Dr. Paul Somerville

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Dr Dan O'Connell
US Bureau of Reclamation
Bldg 67, D-8330
6th and Kipling
Denver, CO 80225-0007
Tel (303) 445-3176
Fax (303) 445-6478
Email geomagic@seismo.usbr.gov

Re: Review of "**Ground Motion Evaluation for Jackson Lake Dam, Minodoka Project, Wyoming**" by D. O'Connell, C.K. Wood, D.A. Ostenaa, L.V. Block, and R.C. LaForge, Draft Report dated January 2003.

Delivery Order 01A10810210H, USBR Contract 01CS 20210H

Dear Dr O'Connell

I am writing to document my review comments of the above report. My comments were conveyed during the daylong review meeting that was held at the offices of Dr Ralph Archuleta at UCSB on March 10, 2003. During that meeting, I watched as you edited the draft PDF version of the report on the screen, and can confirm that you correctly noted down the detailed comments that I made during the meeting. Most of these comments relate to more detailed documentation of information that is presented in the report. As I indicated at the review meeting, I am not very familiar with nonlinear soil response analyses of the kind described in Sections 6.6 and 7.8, and in Appendices E and F, and so some other person should review those sections of the report. Incidentally, these analyses are not described in the Objectives and Scope of Section 1.2. The specific comments that I present below are intended to document the main issues that were raised in my review of the report, and my suggestions on how those issues might be addressed.

Before addressing those issues, I would like to state that I am very impressed with the high level of careful thought and technical expertise that is embodied in the work that the report describes. It is well known that earthquake ground motions are characterized by a high degree of variability. In recent years, seismologists and geotechnical engineers have identified several conditions that can give rise to unusually large ground motions. These include rupture directivity effects and basin effects. The report describes the rigorous use of earthquake recordings of the JLD array and the JLSN to identify the seismic velocity structure of the region surrounding the dam, including the Jackson Lake Basin, and to explore to seismic wave propagation characteristics of the site region using these recordings. The report also describes ground motion simulations that make use of the derived seismic velocity models and rigorous seismological theory (the elastodynamic representation theorem).

The presence of a deep sedimentary basin on the hanging wall of a major active fault presents significant challenges to making realistic estimates of the ground motions at the dam site. The report's realistic treatment of the laterally varying seismic velocity structure of the site region, reflecting its complex geology, is a notable feature of the report. Through the analysis of dam site recordings and through ground motion simulations, the report demonstrates that the ground motions at the dam site may be significantly different from those that might be estimated using simpler and less site-specific methods, such as empirical ground motion attenuation relations.

Topic 1. Level of simulated ground motions

The simulated ground motions for rock site conditions are larger than predicted by the empirical model of Spudich et al. (1997). They are typically as large as the predicted levels for soil site conditions at periods less than about 2 seconds, and substantially exceed those levels at periods longer than 2 seconds. They are also larger than is commonly observed in near-fault recordings of past large earthquakes at these longer periods, as documented in the 17-page handout that I gave you at the review meeting. These large ground motion levels have several potential causes:

a.Near fault rupture directivity effects. These effects are manifested in the simulations in their pulse-like character and in their larger strike-normal than strike-parallel components. However, the site is not so close to the fault that it would see maximum rupture directivity effects – this is demonstrated in Figures 4-20 and 6-11. (Incidentally, these two figures appear to be inconsistent, with more rapid attenuation of ground motion to the east in Figure 4-20 than in Figure 6-11; this apparent discrepancy needs to be resolved). Also, the recorded ground motions close to large dip-slip earthquakes, e.g. from the Northridge, Chi-Chi, Taiwan, and Tabas, Iran earthquakes, are no larger than the simulations. A comparison of simulations with the Tabas earthquake is provided in Figure 5-17, showing much larger long period ground motions (periods longer than 1 second) in the simulations than in the Tabas record. Another example of apparently unrealistically large ground motions is Figure 6-37, where the vertical component is as large as the horizontal component at periods longer than 2 seconds – I do not know any recordings that show such features.

b.Basin effects. These effects are not so clearly manifested in the simulations – if present, they are included in the large initial pulses of motion. There are no good data analogs for the hanging wall basin condition at the dam site, so perhaps the very large simulated ground motions are due to that unique combination of conditions. The best analogs may be the near-fault recordings of the 1979 Imperial Valley earthquake and the 1980 Mammoth Lakes earthquake.

The following approaches are suggested to test whether the large long period ground motion levels in the simulations are realistic.

(i).Examine Dam Recordings of Larger Earthquakes. Dam site recordings of local and regional earthquakes that are large enough to generate long period waves above the noise level (longer than 1 second) can potentially provide empirical confirmation of large ground motion levels at long periods. (The earthquakes that were analyzed in Sections 4 and 5 of the report were all so small that their long period ground motions were below the noise level). The response spectra of these larger earthquake recordings should be calculated to assess their spectral shape. If they have relatively large response spectral levels at long periods, this would constitute empirical confirmation of the simulations. Simulation of the ground motion recordings, using independently determined seismic moments and focal mechanisms, would provide a quantitative test of the realism of the seismic wave velocity model and the wave propagation models used in the simulations. If the recorded ground motions are reproduced by the simulations, this would provide further confirmation that the basin effects are being accurately represented in the simulations.

Independently determined seismic moments and focal mechanisms of these earthquakes are needed, because the goal is to check the ground motion levels recorded at the dam site; these JLD array recordings ideally should not be used to estimate the seismic moment and focal mechanism because to do so would be to employ circular logic. Ideally, broadband recordings outside the basin would be used, but such recordings are evidently unavailable because all of the JLSN network stations are narrow band stations. Perhaps nearby NSN stations can be used instead for this purpose.

(ii).Perform Simulations without the Basin. Perform simulations of ground motions at the site using the same surface layer velocities but removing the approximately 3 km thick basin. Comparison of these simulations with those calculated using the basin structure would provide a means of quantifying the effect of the basin on the ground motions.

(iii).Validate the Simulation Procedure. It is important to show that the simulation procedure does not overpredict the recorded ground motions of past earthquakes. Kinematic rupture models of past earthquakes provide a means to simulate the recorded ground motions of those earthquakes, and compare the two. The 1979 Imperial Valley and 1980 Mammoth Lake earthquakes, together with dip-slip thrust earthquakes with many recordings, such as the Northridge and Chi-Chi earthquakes, would seem to be good candidates, in the absence of well recorded normal faulting earthquakes.

Topic 2. Earthquake Recurrence

Section 2 of the report implies considerable uncertainty in the recurrence of large earthquakes that might affect the site. Although the simplest model suggests that large events on the Teton fault have average return intervals of about 1700 – 2000 years (Section 2.3.4, page 40), this section also states that "Overall, the average intervals of large surface-rupture events on the Teton fault could be as low as a several hundred years or as long as a few thousand." If earthquakes occurring every few hundred years could potentially liquefy parts of the dam or its foundations, this could have a very significant impact on the seismic hazard at the site, because it would represent a hazard that occurs with a frequency that is an order of magnitude higher than has been assumed in Section 7.

Section 3.6 of the report describes recurrence interval estimates for magnitude 6 earthquakes in the Jackson Lake region (515 to 635 years) that are 3 to 4 times longer than those of a larger region of the ISB as estimated by Wong and Arabasz (170 and 158 years respectively). However, these longer estimates are based on smaller magnitude earthquakes, and may not pertain to the larger earthquakes (of magnitude 6 and above) that pose a potential hazard to the dam. If this lower recurrence is used, it needs to be rigorously justified on the basis of a physical explanation as to why the Jackson Lake region has longer earthquake recurrence intervals for magnitude 6 and larger earthquakes compared with that of the larger ISB region.

The report contains contradictory statements about the importance of smaller magnitude earthquakes; these need to be resolved. On page 287 there is the statement (which sounds reasonable to me) that "Because this section only considers the Teton fault as a seismic source and background seismicity clearly increases the seismic loading rates (Section 3), it is necessary to increase annual exceedance probabilities relative to activity rates of the Teton fault to provide representative probabilistic seismic load for dynamic analyses of the dam." However, on page 307 there is the statement (Section 7.6) that "Since the random seismicity did not significantly contribute to PHA exceeding 0.5 g (see Section 3 and Wong et al., 1999), only ground motions associated with the Teton fault were considered."

Topic 3. Estimates of Annual Probabilities

Sections 7.6 and 7.7 provide estimates of the annual probability of occurrence of a series of peak acceleration values and ranges. However, a probabilistic seismic hazard curve is needed to rigorously estimate these probability levels, and no such hazard curve is presented. More explanation is required of the approximate method that was used to estimate the annual probabilities of occurrence. Ideally, they would be based on a probabilistic seismic hazard curve. It is recognized that standard ground motion models, such as that of Spudich et al. (1997), that might be used in such a probabilistic hazard analysis, are not site-specific, and might need adjustment to accommodate the site-specific ground motion characteristics at the dam site.

Topic 4. Nonlinear Soil Response Analyses

At the review meeting, it was pointed out by Prof. Ralph Archuleta that there are substantial differences between the results of the nonlinear soil response analyses described in Section 6.6 and Appendix F. Specifically, the peak shear strain increases in the liquefiable zone in the former and decreases in the latter. Drs Archuleta and O'Connell plan to compare input parameters to resolve this discrepancy.

Topic 5. Source Parameters used in Simulations

There needs to be more documentation of the source parameters used in the simulations, with some justification of the values used. This includes parameters such as the seismic moment, rupture area, rupture velocity, and rise time. Also, I think that 45 degrees is a more justifiable dip angle for the fault than 35 degrees. A review of recent normal faulting events in the western United States having reliable focal mechanisms (e.g. 1983 Borah Peak – 49 degrees) would, I expect, substantiate this. While recognizing the issue of possible deficiency in the Green's functions, I think it would be preferable to use simulations that have a dip angle of 45 degrees.

Topic 6. Spatial Incoherence of Ground Motions

Section 7.9 describes the potential importance of the spatial incoherence of ground motions. Methods are available for generating a suite of ground motion time histories at separate locations that are mutually compatible in that they represent realistic spatial variations, as defined by an empirical coherency model, in the ground motion time histories at adjacent locations. The empirical model could potentially be checked against ground motion recordings of the JLD array, by computing the coherence of such recordings and comparing it with the empirical model.

Editorial Comments

The Executive Summary should be briefer and more focused on describing the products of the work for use in subsequent analyses than on providing the details of the methodology. Much of the existing Executive Summary could be integrated into Section 7 – Conclusions.

Please let me know if you need any clarification of these comments.

Sincerely,

Paul Somerville
Principal Engineering Seismologist
URS Corporation
Pasadena, California